

DISTRIBUTION OF THE OHIO BROODS OF
PERIODICAL CICADA WITH REFER-
ENCE TO SOIL

OHIO
Agricultural Experiment
Station

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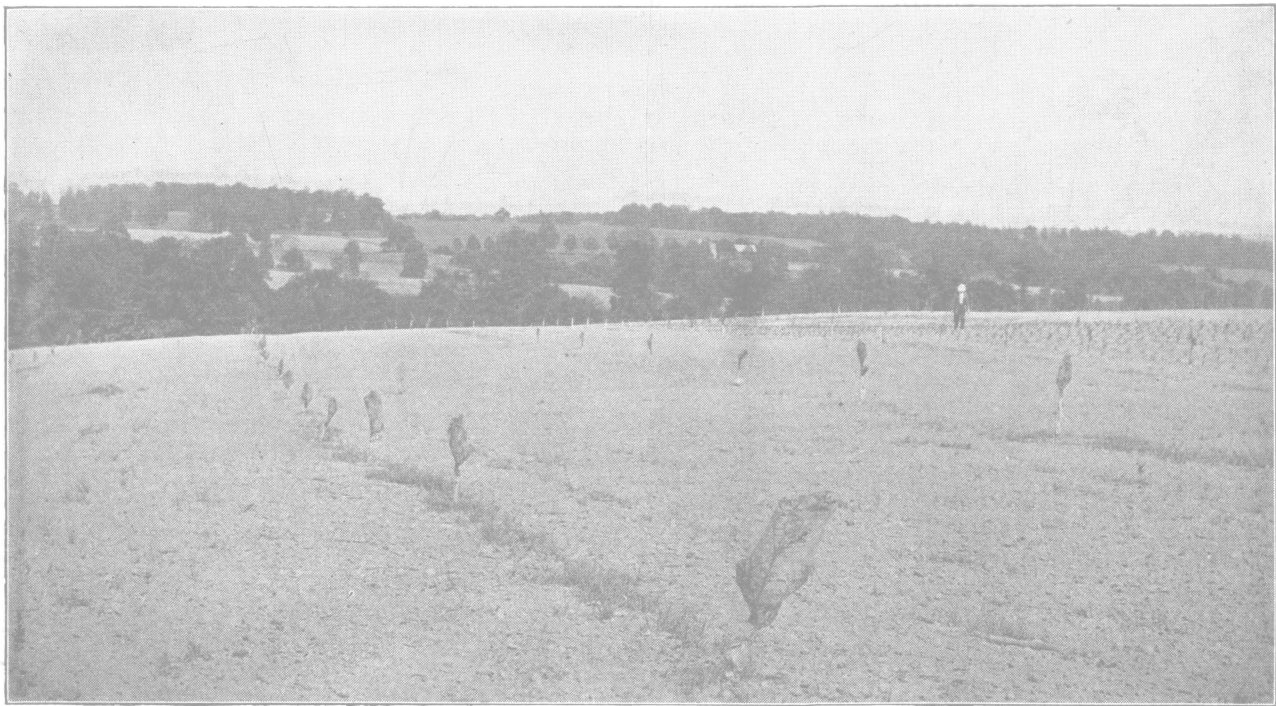
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Young apple trees protected from periodical cicada by means of mosquito netting over tops and paper wrapping around trunks (Wooster, Ohio, 1914 brood)

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DISTRIBUTION OF THE OHIO BROODS OF PERIODICAL CICADA WITH REFERENCE TO SOIL¹

H. A. GOSSARD

In the spring of 1914, I read before a literary club at Wooster, Ohio, a paper on the periodical cicada. To illustrate the paper, I submitted maps showing the areas occupied by the more notable Ohio broods of the insect. Among my auditors was George N. Coffey, who was then working on the State Soil Survey in cooperation between the Bureau of Soils, U. S. Department of Agriculture, and this Station, and who later published a soil map of the Reconnaissance Soil Survey of Ohio from the U. S. Bureau of Soils, issued by the Government Printing Office in 1915.

Doctor Coffey instantly recognized that the brood maps for the periodical cicada coincided in a most striking way in their general outlines with the soil maps established by his survey. Subsequent comparison and study of these maps has satisfied me that a definite relation must exist in most of these Ohio cases between the distribution of cicada broods and the soil areas over which they occur. While such relationships may be obscure or lost in case of some broods, both outside and inside the State, and while their distribution may sometimes depend wholly or in part on other than the soil factor, I cannot escape the conclusion that this has been a potent cause in determining the limits of several of our Ohio broods. An alternative conclusion is that the causes that fixed the soil areas at the same time directly operated to determine the cleavage lines between the broods—to my mind a more improbable supposition.

AREAS OF BROODS V AND X

Let us first compare the map prepared by Prof. F. M. Webster in 1897 for the brood of that year, or Brood V of Marlatt (p. 567), with Doctor Coffey's map (p. 564) and also with the geological map of Ohio (p. 565) prepared by J. A. Bownocker, state geologist, 1909.

¹Paper read before the Entomological Society of America, New York Meeting, 1916-17

Notice that the eastern boundary lines of three large soil areas extending across the State from north to south—viz, the Miami silt loam, the Cincinnati silt loam and the Colbert silt loam—coincide almost exactly with the western boundary of Brood V, this boundary being also the western limit of the Volusia silt loam and the DeKalb silt loam. On my map of the 1914 distribution of this brood (p. 568), where each dot represents a report of the presence of cicadas and every square a swarm of the insects, the coincidence is even more strikingly shown. In other words, this brood flourishes on the last two soil areas named, and disappears abruptly and completely at the border of the first three. West of the division line is the 1919 brood, or Brood X of Marlatt (p. 569).

By comparing my brood map (p. 568) with Bownocker's geological map (p. 565), the western boundary of the brood is seen to coincide with the western boundary of the Waverly and Maxville shales, sandstones and limestones. The brood ceases abruptly at the eastern boundary of the dolomitic limestones which underlie the western half of the State. These limestones are of remarkable purity, according to our geologists, who say:¹ "The clay or sand or iron coloring matter falls below 2 percent in hundreds of places. The composition, however, is generally dolomitic; i. e., the stone is a mixture of carbonate of calcium and carbonate of magnesium, the proportions often becoming those of the mineral dolomite itself."

COMPARATIVE DESCRIPTION OF SOILS

Let us again direct our attention to the surface soils west of the brood line and note their descriptions as given in the Reconnaissance Survey:

Miami silt loam.—To the west of the brood line, the Miami silt loam in the north usually occurs in three and sometimes in four zones, or layers. The surface soil to a depth of about 8 inches is a grayish-yellow or light grayish-brown silt loam. The upper zone of the subsoil, extending to an average depth of about 16 inches, is a yellow, friable heavy silt loam or light silty clay loam. Below this stratum is found a yellowish-brown, compact clay which is hard and has a tendency to break into cubes when dry, but to become plastic and sticky when wet.

Cincinnati silt loam.—The Cincinnati silt loam, next in order going southward, is so similar in most of its characteristics that it is extremely difficult to draw a boundary between the two. Were it not for the heavier nature of the subsoil and the presence of limestone fragments on the surface, it would be almost impossible to

¹Ohio Geological Survey, Bul 4, p. 24.

separate these two silt loams from each other, except where the Cincinnati formation has a layer of drift between the loess and the limestone.

Colbert silt loam.—The Colbert silt loam, the southernmost of the three areas, consists of a grayish-brown or light-yellowish brown, mellow silt loam with a depth of 8 to 11 inches. The subsoil is a yellow silt loam to silty clay loam, grading at about 20 inches into a yellow silty clay which is often very stiff and plastic in the lower part of the 3-foot section. The upper part of the subsoil is usually yellow, grading at various depths into a dull yellow and in places in the lower part to a rather dark yellow or brown. Marl is sometimes found within 20 to 26 inches of the surface. The subsoil seldom effervesces where the limestone rock is not encountered within 3 feet of the surface.

Volusia silt loam.—Of the soils to the east of the line, the Volusia silt loam in the north consists of a grayish-brown, smooth silt loam, about 7 or 8 inches deep, underlain by a pale-yellow or yellow mottled with gray silt loam, which grades at about 12 to 15 inches into a mottled gray and yellow, heavy, silty clay loam. The subsoil is comparatively heavy, mottled with gray, as well as with brown iron stains, and there is often a tendency to form a hard compact layer at a depth of about 20 inches. The Volusia silt loam is of glacial origin, being formed from a mantle of drift over the underlying shales and sandstones, which are usually not many feet below the surface. The surface is rolling to somewhat hilly; and, while this provides good surface drainage, the heavy character and rather impervious nature of the subsoil cause this type to be somewhat "cold" and wet for many days after a rain, especially in the spring.

DeKalb silt loam.—The DeKalb silt loam to the south of the Volusia area is a grayish-yellow or light yellowish brown, mealy silt loam, varying in depth from 6 to 12 inches with an average of about 9 inches. Where the underlying rock consists of sandstone, the soil contains a somewhat higher percentage of fine sand than where the rock is composed largely of shales, grading into the DeKalb sandy loam. The subsoil is a yellow to brownish-yellow, rather heavy silt loam or silty clay loam, attaining its heaviest texture at a depth of 18 to 24 inches, below which it becomes gradually more porous as the partly weathered rock is approached, especially where the underlying rock is sandstone instead of shale. The depth of the soil and subsoil over the sandstones and shales varies from a few inches to 6 feet or considerably more, with an average depth for the whole area of not more than 3 feet.

Fuller information regarding these soil areas may be obtained from the publication from which these extracts were taken.

POSSIBLE ECOLOGICAL FACTORS

We thus see there is no outstanding factor of difference between the soils on either side of the dividing line except that those east of the line are more likely to be acid than those west of it, and the underground drainage east of the line is somewhat poorer than west of it, producing a colder soil in the spring. However, there are spots east of the line underlain with limestone just as west of it; and so far as present knowledge enables us to speak, the cicadas appear over these at the same time and in the same numbers as over the surrounding sandstones.

Relative temperatures of areas.—The soil experts at the Ohio Station are not prepared to state with any positiveness that the average temperature of the soils east of the line is any different from that of the soils west of it. However, such studies of soil temperature as are reported in Technical Bulletins 17 and 26 of the Michigan Agricultural Experiment Station lead them to suspect that the average temperatures of the different areas will differ to some extent. There is little difference in the color of the surface soils in the two areas. There are much larger areas of blackish or dark soil in the western than in the eastern area, but we have no evidence that the cicadas of the 1919 brood are either more or less numerous on these spots than in surrounding territory. This brood line cuts at almost right angles the isotherms of the State (p. 572), and the average temperature for the northern counties, which it divides, is 5 degrees lower than for those at the southern extremity. The average annual temperature for Erie, Huron and eastern Seneca Counties is 50° F., while it is 55° F. for Ross, Pike and Scioto Counties. It is well-nigh certain that the difference between average soil temperatures in adjacent areas, east and west of the dividing line, is much less than this, and probably negligible.

Rainfall and sunshine.—Generally speaking, there is a somewhat heavier rainfall in the eastern than in the western part of the State. Still, the lines marking the zones of average annual precipitation (p. 573) extend for the most part east and west and are, therefore, cut at right angles by the brood line. The average number of sunshiny days is somewhat greater in the western half of the State than in the eastern, but certainly no difference in this respect can be told in the eastern and western parts of the counties traversed by the brood line.

Underlying rocks.—As previously stated, the only sharply defined factor of difference between the two areas is the underlying limestone rock of the western and the underlying sandstones and shales of the eastern. The soils of the eastern area are therefore more acid than those of the western, and the plants of the western area will have more lime in solution in their sap and built into their tissues than those in the eastern. Whether the presence of lime in the soil on one side of the line and its relative absence on the other can stimulate or retard development in some direct way as by acting on chitin formation, or indirectly through chemical constituents of the food, or whether some drainage factor operating at a critical stage, as at pupation, or a temperature factor must be found to explain the phenomenon, we have at present hardly sufficient data upon which even to speculate; but as our knowledge of soil physics gradually augments, we can hope to solve the query.

That other forms of life than cicadas are governed by these same unknown factors is shown by the fact that certain trees and plants are characteristic of each area. The chestnut tree is common over the sandstones but will scarcely grow in the western limestone section. Alfalfa and the clovers grow more readily in the western half than in the eastern.

THEORIES OF BROOD FORMATION

Influence of glacier.—Professor Webster, in speculating upon the problem of distribution, said:¹

“Just why our periodical cicada should require so long a time to develop, and why the adult should appear in different places in the United States, during fourteen out of the cycle of seventeen years, it is impossible to say. My own suspicion, in reference to this phenomenon, is that a glacial period may have had its influence in retarding the development of the species for different periods of time, in different localities. This, however, is to be taken as an unsubstantiated possibility; but there certainly must have been some influences, in the past, that have retarded or accelerated the development of these insects, and have not exerted the same influence over the entire area of the distribution of the species.”

By comparing the brood maps with the glacial map of Ohio (p. 566), we see that the glacial lines are cut straight across by the brood line, and it seems impossible that different glacial influences operated in adjacent territory on the two sides of the line.

¹Ohio Agr. Exp. Sta. Bul. 87, p. 39.

Splitting off from main brood.—The influencing factors, whatever they may have been, have probably operated slowly, breaking the broods apart a year at a time; and rarely or in no case has the gap of several years between two adjacent broods been spanned at a single leap. The scattering thin swarms which precede or follow a great brood by a year's time are probable examples of such splitting off from the main brood. If these are numerous enough to breed, and are added to again at the next appearance of the brood, and these are regularly augmented in number with each recurring appearance of the parent brood, it is conceivable that the new brood thus formed will eventually surpass in numbers the brood from which it sprang, and that the same influences, being continued, will again in time push the new brood a year ahead or leave it an additional year behind, as the case may be, thus putting 2 years between it and the parent brood, which gradually disappears over the areas where the retarding or accelerating influence is acting. It apparently must be that the influence for change is slight but exerted quite constantly in the same direction either to retard or to accelerate development. Hence, a year is lost or gained by a small number of individuals, but if any of this new brood are precipitated ahead or behind their season as a consequence of the same influence, the numbers will be so small they cannot easily mate and all traces of them are soon lost. Therefore, a populous brood can be forming a new one a year earlier or later than its own appearance but the new brood must, in general, keep the same interval between its appearances as the parent brood. The original date will be kept in territory where such influence for change is not present. Extending the influence for change over yet longer periods, we can account for two broods appearing in adjacent territory, separated from each other abruptly as are most of the Ohio broods.

Influence of environment.—This conception of brood formation should be compared with that stated by Marlatt:¹ "It is a well-known phenomenon in connection with insect life that whatever may be the period of development of a species certain individuals will often, for some reason or other, such as insufficient or unsuitable food, unfavorable temperature or other conditions be delayed or retarded, while others, for reasons the converse of the last, namely, conditions exceptionally favorable, will develop more rapidly or will be accelerated and appear earlier. Therefore, under the former conditions we have a longer and under the latter conditions a shorter life period."

¹U. S. Dept. Agr. Bur. Ent. Bul. 71.

"This is true to a slight degree at the present time of the periodical cicada, and especially with the larger broods has it been noticed that scattering individuals appear the year before and others the year after the great brood year. It is not difficult to imagine, therefore, that under exceptional conditions some of the earlier appearing individuals or the later ones may occur in sufficient numbers to establish a well-marked peculiarity in this direction and form a new brood appearing a year earlier or a year later than the original one. If in the long course of years some accident should happen to the parent brood in that portion of its range the derivative brood might be left to hold the territory alone or to become the predominant swarm.

"It is possible to conceive also of conditions which would result in the acceleration or retardation in the development of an entire brood or broods of the cicada, such as variation in climatic conditions, geological changes, or changed conditions of the topography of the country, including the character of the vegetation."

FURTHER DATA REGARDING BROOD X

The 1919 brood, or Brood X of Marlatt (p. 569), has not been accurately mapped; but so far as the records supplement the map in Bulletin 71 of the U. S. Bureau of Entomology (p. 51), this brood may be said to cover nearly all Ohio west of the boundary of Marlatt's Brood V. An old record, which was not confirmed in 1902, has the brood reported in Columbiana County, and it was also proved to be present in Gallia County. These counties contain formations where limited limestone outcrops may occur, and if the cicadas appear in them again in 1919, I shall be interested to locate the insects definitely and ascertain whether the underlying formation where they are found is similar to that in the western half of the State where the great body of the brood is located. Several counties in northwestern Ohio are conspicuous because of the absence of the brood, while the cicadas surround these counties by spreading out through northern Indiana and southern Michigan. These counties were all occupied in glacial times by a southwestern extension of Lake Erie, this old glacial lake extending as far west as Fort Wayne, Ind., being known to geologists as Lake Maumee, and in later glacial times when it had receded considerably from its original shores as Lake Whittlesey and yet later as Lake Warren.

The soils in these counties are classed the same as extensive tracts which were lying outside of and bordering this old lake but were not submerged in glacial times. These counties, in an early

day, constituted the "flatwoods" region of Ohio and were swampy, malarial districts until within the last 50 years. Perhaps conditions have not been congenial for the spread of cicadas into such counties since glacial times. The insects are reported from Lucas County, which was submerged by the glacial lakes except for one small corner which was not covered by Lake Warren but was covered by both the earlier lakes. If the brood appears again in Lucas County in 1919 the exact locality will be of much interest.

BROOD VIII

Brood VIII of Marlatt (p. 570), due to appear in 1917, is interesting because with the exception of two counties bordering Lake Erie it exactly fills up the area in northeastern Ohio from which Brood V is absent. Broods V, VIII and X of Marlatt cover nearly the entire State and when considered separately constitute a dissected map, which, with the exception of the few northwestern and northeastern counties already noticed, is an almost perfect outline of the State when the sections are put together.

The counties occupied by the 1917 brood, according to Marlatt, are Portage, Trumbull, Mahoning, Stark, Columbiana, Carroll, Jefferson and Belmont. The brood, however, seems to be massed chiefly in the first five counties on the Volusia and Trumbull series of soils, though there are some records to the south on the DeKalb silt loam. The soils of these counties are light in color, from gray to grayish-brown or yellowish-brown, and have mottled subsoils, the mottling being due to the presence of iron. The soils are flat, poorly drained and strikingly deficient in lime. There is a tendency to the formation of an iron hardpan in the subsoils, and a peculiar imperviousness to water causes these soils to be ranked as the coldest and slowest drained in the State. The average rainfall is high in these counties (p. 573) and the average number of crop-growing days per year (p. 574) the fewest in the State. It is the region of lowest mean annual temperature (p. 572) and of greatest annual snowfall (p. 575).

If the distribution of this brood is governed to any extent by type of soil, we have yet to seek some reason why the insects are not found in Geauga, Lake and Ashtabula Counties and why they extend down into Carroll, Jefferson and Belmont Counties. Professor Webster records¹ that near Painesville, Brood V occurred some 3 miles nearer to the lake shore in 1846 and in 1863 than it did in 1880 or 1897 and there may have been a like gradual recession of Brood VIII

¹Canadian Entomologist, October, 1897.

from the counties bordering the lake shore. All the counties occupied are underlain with sandstones and shales. It is readily seen that temperature and drainage factors may operate much more vigorously here than in the sections covered by the other broods, and may here be the predominant factors affecting distribution.

BROOD XIV

Brood XIV of Marlatt (p. 571) is the only other important brood in Ohio. I mapped it carefully in 1906. It is interesting because it crosses transversely the southern parts of the areas occupied by the greatest two broods of the State, and occurs on both the western limestone and the eastern sandstones, but more conspicuously on the former. It cuts across surface soil areas with seeming indifference, and if soil character has had any effect on its distribution this is hardly apparent at present, unless its preponderance on the limestone soils indicates that it is gradually disappearing on the sandstones and shales. This may be the original or parent brood for all the Ohio broods, having gradually receded from the lake shore until it is now confined to the southern counties.

The lines of mean annual temperature (p. 572), of last killing frost in spring (p. 576), of average number of days in the crop-growing season (p. 574), of average annual precipitation (p. 573), of average amount of precipitation in spring (p. 577), and of annual snowfall (p. 575) are all possible influences to fix the boundaries of this brood, and a study of the maps which suggest that these factors may have influenced its present distribution is of deep interest.

Fig. 1.—Soil map by Coffey and Rice—Reconnaissance Soil Survey of Ohio, U. S. Department of Agriculture, Bureau of Soils in cooperation with the Ohio Agricultural Experiment Station, 1915.



A.—Miami silt loam; B.—Cincinnati silt loam; C.—Colbert silt loam; D.—Volusia silt loam; E.—DeKalb silt loam. The heavy black lines have been added to show separation lines of these areas. The central line also separates the western limestones from the eastern sandstones and shales.

Fig. 2.—Geological map of Ohio by J. A. Bownocker, state geologist, 1909



The dark line has been added by H. A. Gossard to make the division between the dolomitic limestones to the west and the Waverly and Maxville shales to the east as determined by Bownocker. (From Report of Bureau of Soils, U. S. Dept. Agr., 1912.)

Fig. 3.—Glacial map of Ohio

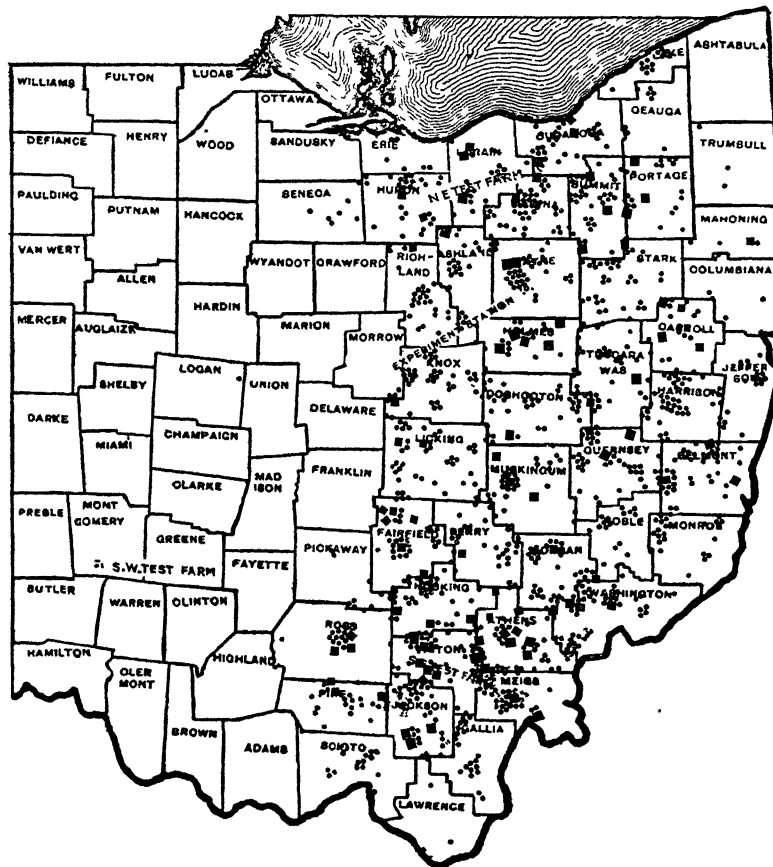


Shaded portion in the southeast, unglaciated region; dark mulberry area in southwest, early Wisconsin drift; light dotted area contiguous to unglaciated area, moraines; fine, faintly dotted areas, late Wisconsin drift. (Photographed from U. S. Geological Survey, Monograph XLI, Pl. II. Survey by Frank Leve-rett, 1900.)

Fig. 4.—Distribution of periodical cicada, Brood V of Marlatt,
prepared by F. M. Webster, 1897



Fig. 5.—Distribution of periodical cicada, Brood V of Marlatt, from data gathered by H. A. Gossard, 1914



Each dot indicates a trustworthy report of the presence of the insects and each square a swarm of them.

Fig. 7.—Tentative map of periodical cicada, Brood VIII of Marlatt, due in 1917



The insects appeared in the dotted counties in 1900, but probably the dots should be located farther east in the counties of Portage, Stark and Carroll.

Fig. 8.—Distribution of periodical cicada, Brood XIV of Marlatt, from data collected by H. A. Gossard in 1906



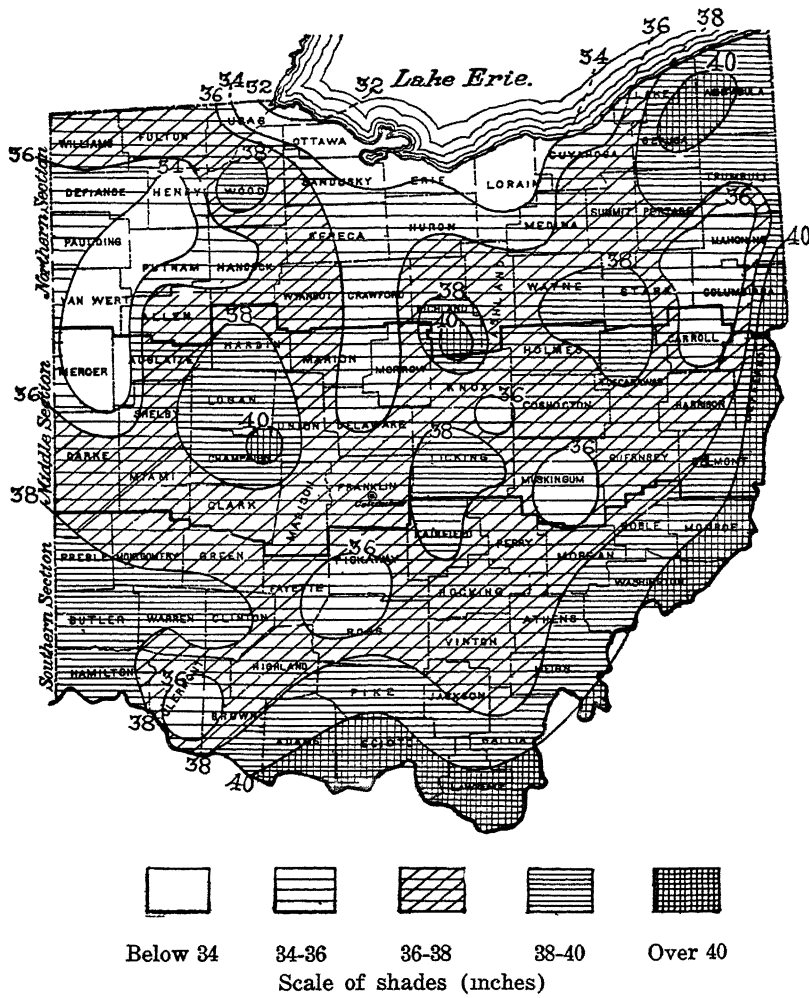
The black squares indicate swarms of cicadas

Fig. 9.—Mean Annual Temperature



The average annual temperature lines are drawn on the chart for each degree. The coolest sections of the State are in the northeastern and northwestern districts, while the warmest are in the extreme southern and southwestern counties. These isothermal lines are regular in the southern portion of the State, bending to the north when they cross the valleys and to the south over the uplands. There is a large area in the west-central and northwestern counties, however, where the average temperature varies less than 1 degree for a distance of more than 100 miles, from Champaign to Ottawa Counties. The lowest annual mean temperature is 47.2° in Portage County, and the highest, 55.5° in Scioto County. (From Ohio Exp. Sta. Bul. 235, p. 197.)

Fig 10.—Average Annual Precipitation



The average annual precipitation for the different sections of Ohio is shown graphically on this chart by means of shaded areas. Lines are drawn for each difference of 2 inches from 34 inches to 40 inches, and areas having the same precipitation are given the same shading. The greatest precipitation is along the Ohio River, and the least near the western end of Lake Erie. There is a large district in the western portion of the State with a rainfall of less than 34 inches. (From Ohio Exp. Sta. Bul. 235, p. 203.)

Fig. 11.—Average Number of Days in Crop-growing Season



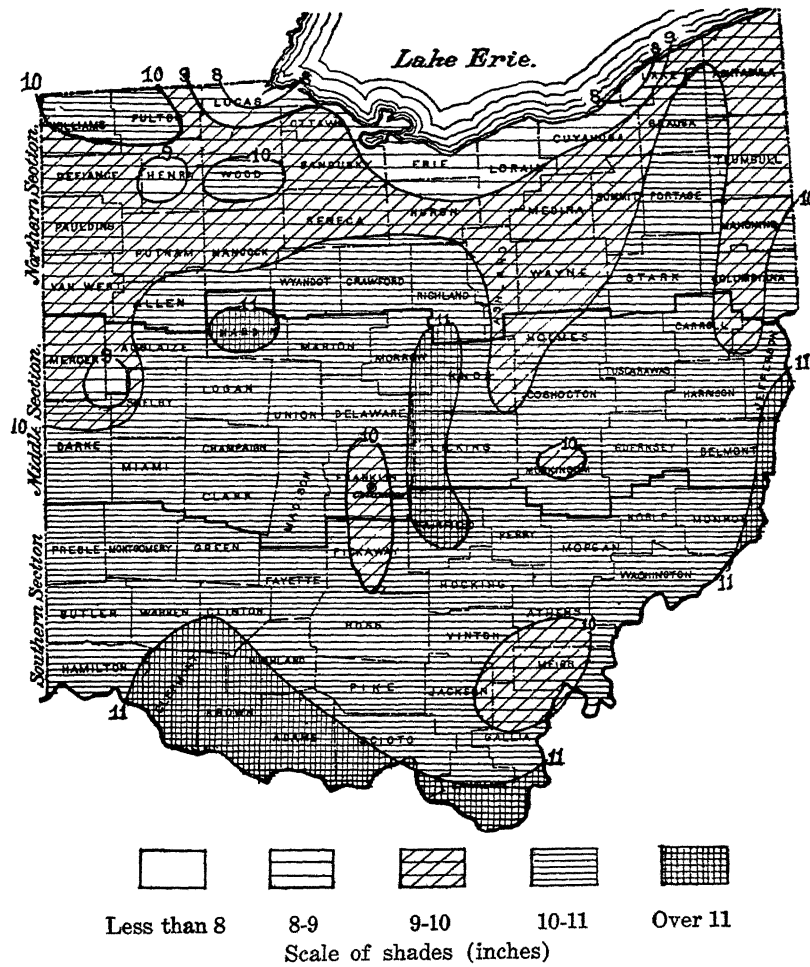
The greatest number of days between the average date of the last killing frost in the spring and the earliest in autumn is 195 at Sandusky, 194 at Cincinnati, and 193 at Cleveland. The smallest number of days is 134 in Portage County. The lines are drawn for each 10 days. (From Ohio Exp. Sta. Bul. 235, p. 202.)

Map of Ohio showing the distribution of annual precipitation in inches by county. The map is divided into three horizontal sections: Northern, Middle, and Southern. Precipitation levels are indicated by different shading patterns: white for 'Less than 20', horizontal lines for '20-30', diagonal lines for '30-40', vertical lines for '40-50', and a grid pattern for 'Over 50'. The map includes latitude and longitude markings and labels for major cities and bodies of water like Lake Erie.

In this chart is shown the distribution of the average amount of unmelted snow that falls each year. Lines are drawn for each difference of 10 inches and then the areas shaded as in the preceding charts. This shows that the average snowfall is less than 20 inches in the extreme southern counties, and more than 60 inches over a small area in the northeast. This district of greatest snowfall corresponds with or is just to the north of the highest land between the southern and northern watersheds. (From Ohio Exp. Sta. Bul. 235, p. 208.)

The average dates of the last killing frosts of spring are indicated on this chart by lines that are drawn for each 5 days. The latest killing frosts in the spring occur in the northeastern counties at some distance away from the Lake, and there they average slightly later than May 15. They average earlier than April 20 along the Lake and in some southern districts. (From Ohio Exp. Sta. Bul. 235, p. 198.)

Fig. 14.—Average Amount of Precipitation in Spring



The distribution of precipitation during the spring months, March, April and May, is shown on this chart. Lines are drawn for each inch of rain, from 8 inches to 11 inches, and the different areas are shaded to correspond with the scale at the bottom of the chart. The least fall is near the Lake and the greatest in the central counties and near the Ohio River. (From Ohio Exp. Sta. Bul. 235, p. 204.)